THE EVOLUTION OF THE SPECIAL SENSES.

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BY sensation the mind is cognizant of an outer world; by expression the outer world is cognizant of the mind. All grades of animal life possess in some form organs of sensation. We do not care to except even that substratum of life—protoplasm. This curiously vitalized structure lives and reproduces itself without organs; moves without limbs; takes food without a mouth, and digests it without a stomach. It will not be a surprise when we find that it has sensation without nerves. More properly, it might be considered as a unit of being, functioning as an organ. Of the nature of this sensation nothing definite can be said. It is known that it is irritable, and able to discriminate between food and indigestible substances. Among the unicellular organisms, sensation is of a higher degree, though of the same character as that we find in the indifferent protoplasmic bodies, and the sensation even here is limited to the protoplasm of these organisms. As we ascend the scale of life it is not until we reach the medusa family that we meet the sensory organs sufficiently developed to deserve the name, for here do we find the first evidence of a separate nervous system. Hitherto, throughout the preceding groups, the differentiation had attained only to the neuro-muscular tissue, in which the cell acted in the dual rôle of muscle and nerve. Evidently here was the first opportunity for the appearing of special organs of sense, since sensory organs are but the terminal organs of a sensory nerve. These sensory organs of the medusa are extremely

rudimentary, but they are a forecast of those perfect organs which are to come. The tentacles of the medusæ (jelly fishes) are abundantly supplied with tactile organs, which greatly assist them in their selection of food. An additional amplification of the sensory apparatus appearing at this stage are the "marginal bodies," which are situated upon the margin of the bell of the jelly-fish, and are of sufficient development to manifest the rudiments of an ear and eye. The "ears" are vesicles or sacs filled with a fluid substance, and containing concretions or crystals of lime, attached to the walls, from which run nervous filaments to the ganglionic centres. As the jelly-fish lives in the water, it is readily seen how the vibrations of sound, travelling through the water, could be transmitted to the fluid contents of the vesicle, and how this agitation may cause concussion of the particles of lime, and how, from the connec-

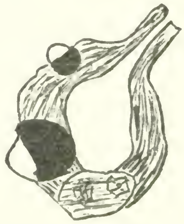


Fig. 1.—Marginal body of medusæ. (After Gegenbaur.)

tion of the nervous fibrils with these concretions, the organism becomes conscious of the sound. The "eyes" are patches of pigment, in which nerve-fibres terminate. Surmounting and imbedded in each of these pigment spots is a transparent, highly refractive lens-like body. Simple as is this apparatus, it possesses the essential elements for vision, truly not as we know it, but sufficient for all the needs of the creature.

Among the vermes, or worm family, may be seen examples of the gradual evolution of the organs from this simple condition to that of a really complex structure. In the lower forms, the eye remains a pigment spot, while, by slight gradations, it becomes in the higher forms an apparatus possessing an expanded optic nerve, vitreous humor, and a crystalline lens. The auditory organs of the

crustacea furnish an example of a direct adaptation of organs of general sensation into those of a special order. These organs lie in a cup-shaped indentation of the integument. The cavities in some instances are closed, and in others open. In the latter case the otoliths are grains of sand brought in from the exterior, which are attached to hairs of the integument enclosed by the indentation. These

Fig. III. Eye of Fish.

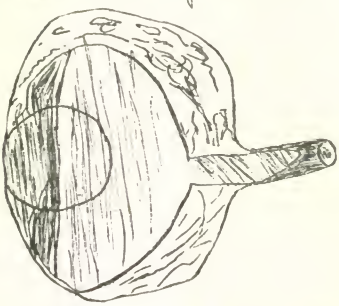
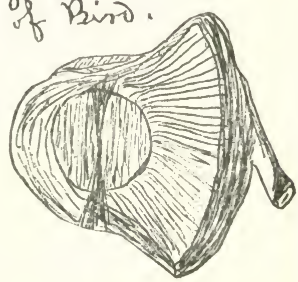


Fig. IV. Eye of Bird.



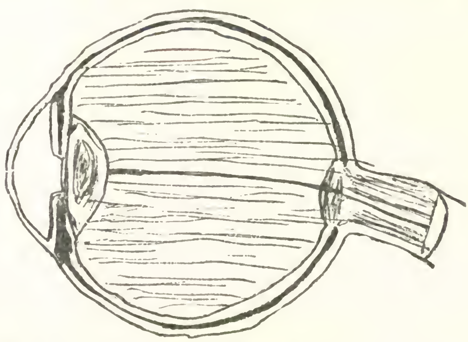


Fig. V. Eye of Man.

hairs are but the modified hairs or tactile rods, which are found scattered over the surface of the body, and with whose roots or bulbs nerve filaments are connected.

In the insecta the development continues. Over the opening is stretched a tympanum or drumhead, and instead of the hairs and sand, there is connected with this drumhead a ridge of regularly-arranged club-shaped rods of nervous structure. Here is the first appearance of the drum-

head. In the eye of the higher mollusca the noticeable features are a recession of the lens from the cornea, dividing the cavity of the eye into the anterior and posterior chambers, and the presence of an iris and pupil. The auditory organs show an approach toward a membranous and cartilaginous labyrinth.

The eye of the vertebrate has three stages in its evolution before it reaches the perfect type of the mammal. The first stage is that of the fish; the second that of the bird, and the third that of man. Although among the invertebrates there is a certain mobility of the eye, only in the vertebrates is found that complex muscular attachment by which the eye is so readily directed in any direction Here also are perfected the integumentary folds—the eyelids,—designed to protect the delicate organ from injury. Since the eyes of the fishes and the cetacea of the mammals are constantly bathed by the water in which they live, it is obvious that any lachrymal apparatus would be superfluous. Consequently they are here absent, but are found among the higher vertebrates. The ear of the fish has a labyrinth and semicircular canals, where the nerve filaments terminate as the end organs or otoliths. The labyrinth undergoes gradual but great modification as we ascend the scale of vertebrates. The most important one is the development of the cochlea. In the fishes it exists as a small eminence or diverticulum; in the birds as a straight cone; while in the mammals this cone is turned upon itself in a spiral manner, and becomes the seat of the organs of Corti.

The tympanum is almost universally present in the vertebrates, and so early as the saurians has receded from the surface, thus forming an external auditory meatus. Connecting the tympanum with the labyrinth is a chain of auditory ossicles, intended to convey and magnify sound. These bones also run from the simple to the complex, as the examination extends from the fishes to the mammals.

The external ear is not met with until a high stage of vertebral development is attained.

I have purposely refrained from noticing the development of the gustatory and olfactory senses, for it is difficult

to speak definitely of these senses at any distance beneath the vertebrates, nor do I conceive it greatly necessary, for the differentiation of the organs of these senses is so slightly above that of the general sense of touch, that when one is satisfied of the evolution of the higher senses, there would be little hesitation in accepting it in regard to the lower. It will be noticed that nature was consistent in her process of evolution, and did not depart, even in the most complete organs, from the first principles with which she started, for the lens-like crystal and pigment spot of the lowest

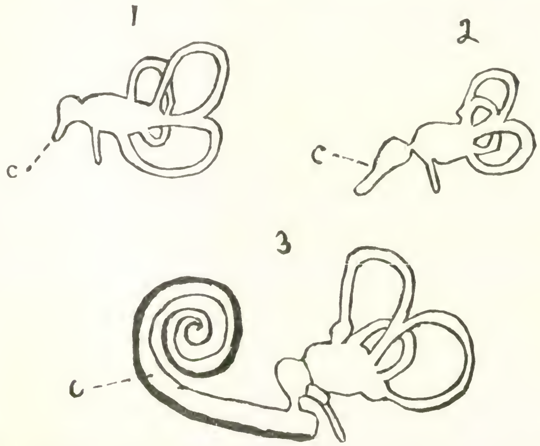


Fig. 2.—Diagrams of labyrinth. 1. Fish. 2. Bird. 3. Mammal. c. Cochlea. (After Waldeyer.)

orders have their analogues all the way up the scale, whether in the crystalline cone and pigment layer of the eye of the insect, or in the crystalline lens, rods and cones of retina, and choroidal (pigment) coat of the human eye.

THE PHYSICS OF SENSATION.

Now that science is conversant with the physics of sensation, it is easy to understand how such an evolution was possible. Sensation is vibration, and the modifications of sensation are but modifications of vibrations. There are no more mathematically exact branches of physics than acoustics and optics, and the essential basis of these is vibration. General sensibility is only possible by actual contact

of bodies in mass, producing a low grade of vibration. This is also true, to a great extent, of the senses of smell and taste, although the particles of the impinging body are more minute. There is associated with general sensation the appreciation of heat, and every student of physics knows that heat is but vibration. Thus we have the senses of touch, taste, and smell, of a group, of low stage of evolution from general sensibility, and necessitating actual contact of bodies or their molecules in order to produce that peculiar vibration which is translated into sensation. It remains to speak of those more elaborately differentiated special senses, viz., hearing and sight. For hearing, the sensory apparatus must be modified to receive vibrations of greater amplitude than those of heat; and for sight, those of lesser amplitude. In the structure of the end organs of these senses, we see the adaptation. In the hairs and grains of sand of the lower forms of life, or the nervous fibrilla and otoliths of the higher forms, we see an organ peculiarly adapted to receive the grosser vibrations of the conducting medium. The refining evolution of the sight organs is not so difficult. The vibrations of light are more closely associated in rapidity to those of heat than are the vibrations of sound. A lens will condense both heat and light vibrations. Indeed, heat is associated as the invisible rays of the spectrum, and lying just beneath the light rays. The apparatus of sight consists of a lens, which condenses the rays, and a nervous plate, which responds to the lowest vibrations of light, yet will not respond to those of heat.

Thus I have attempted to show that consciousness of the material world comes through vibration, and that the special senses are but modifications of the undifferentiated nervous structure, each adapted to vibrations within a narrow limit, and developed for the purpose of widening the horizon of knowledge, and rendering possible a life upon earth other than a purely vegetative one.

THE EFFECT OF USE AND DISUSE UPON THE ORGANS.

While use and necessity develop the special organs of sense, disuse will as certainly allow them to degenerate and

lose their distinguishing characteristics, and the instances illustrating this law of adaptability to environment from trifling changes to complete annihilation are numerous, and it is interesting to note the methods to which nature resorts to overcome or compensate for the obstructions in her path. At great depths in the ocean the light is extremely feeble. Indeed, some animals have given up the use of their eyes entirely, and depend upon their other senses, which, by use, become so acute that they do not miss their eyes, and perhaps consider as myths the traditions of their ancestors that they once saw. Among others, as the crabs, there is an effort made to fight the darkness of the ocean valleys by an enormous development of the eyes, which are sometimes four or or five times as large as those of crabs living at the surface. In addition to this great development of the eye, some marine animals have their eyes phosphorescent, which glow through the dark waters, and light their way ahead, like the head-light of a locomotive in miniature. As if not satisfied with this, some are arrayed with rows of phosphorescent spots along their bodies, which, if the simile may be carried further, are like the lights shining through the windows of the cars. The Niphargus and the Onesimus are animals whose eyes are no longer used, but have the organs of smell and touch highly developed. These organs—and here is the beautiful part of it—are situated upon the antennæ of those which live in the water and where the antennæ are used in the selection of food, and upon the blades of the foot-jaws of those which live and dig for food in the mud of the bottom, where the antennæ could be of no assistance.

There are numerous cases on record where men, having lost their sight or hearing, have developed the acuteness of the remaining senses to a marvellous degree.

The skill of reading by means of the elevated type, and the power of recognizing acquaintances after long intervals by the slightest touch of the hand, are familiar examples of the degree of touch which the blind display. Professor Carpenter, in his Physiology, mentions the case of a blind man "who had acquired a very complete knowledge of

conchology, both recent and fossil, and who is not only able to recognize every one of the numerous specimens in his own cabinet, but to mention the nearest alliances of a shell previously unknown to him when he has thoroughly examined it by his touch"; and that of John Gough, who, though blind, was a noted botanical collector; but what is most wonderful of all, and there are too many instances to leave any doubt, the blind, by means of the touch, have been enabled to distinguish colors, and that upon surfaces similar in other respects.